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Abundance and phenology of Schizomida (Arachnida) from a secondary upland forest in Central Amazonia

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Abundance and phenology of Schizomida (Arachnida) from a secondary upland forest in Central Amazonia. - The 357 Schizomida (short-tailed whipscorpions) collected within 12 months from the soil (0-7 cm depth) of a secondary upland forest (60.4 ± 32.2 ind./m²/month) near Manaus are represented by the hubbardiids *Surazomus mirim* and *S. rodriguesi* (99.7% and 0.3% of the total catch, respectively). About 74% of all specimens of *S. mirim* inhabited the organic soil layer (0-3.5 cm depth) where monthly catches of juveniles were negatively correlated with temperatures of the soil. Females were twice as abundant as males. The lack of a distinct reproductive period and the presence of juveniles (in particular the first nymphal instar) and adults (both sexes) throughout the year indicate a plurivoltine mode of life. Few specimens were caught on the soil surface, none on tree trunks. Abundance of *S. mirim* is compared with that of the Palpigradi (micro whipscorpions) and Uropygi/Thelyphonida (vinegaroons) from the same study site. Schizomids obtained from the soil of four other upland forests in Central Amazonia (0-14 cm depth) accounted for ≤ 0.1% of the total arthropod fauna at these localities and were represented by three additional species.

Key-words: abundance - phenology - Schizomida - Amazon - Neotropics.

INTRODUCTION

Terrestrial arthropods of Central Amazonian forests have been investigated for several years (cf. Adis & Schubart, 1984; Adis, 1997; Adis *et al.*, 1996, 1997a,b) cooperatively between the National Institute for Amazonian Research (INPA) at Manaus /Brazil and the Tropical Ecology Working Group at the Max-Planck-Institute for Limnology in Plön/Germany (Projeto INPA/Max-Planck). Data on abundance and phenology of Schizomida sampled in a secondary upland forest over a 12-month

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period are now available, as their time-consuming taxonomical evaluation has been completed (Cokendolpher & Reddell, 2000). The order Schizomida presently comprises about 220 described species (Adis & Harvey, 2000). Few studies have been conducted on their ecology and biology. Schizomids are considered to be hygrophilous, photophobic, hemiedaphic inhabitants of soils, particularly in the tropics and subtropics. Some species are termitophiles, myrmecophiles, nidicoles or troglobites (cf. Humphreys *et al.*, 1989; Moritz, 1993; Reddell & Cokendolpher, 1995; Rowland, 1972). Our data given here on *Surazomus mirim* represent the second contribution on the phenology of a Neotropical schizomid species (cf. Adis *et al.*, 1999). The results of this contribution were orally presented at the 15th International Congress of Arachnology (March 2001) in Badplaas, South Africa.

STUDY AREA, MATERIAL AND METHODS

Schizomids were collected between 1981 and 1983 in the course of ecological studies on Central Amazonian arthropods from a secondary upland forest where the vegetation was previously cut but unburned. This forest is located at Rio Tarumã Mirím (03°02'S, 60°17'W), a tributary of the Rio Negro near Manaus, and was previously investigated and described (cf. Adis, 1992; Franklin *et al.*, 1997). The area is subject to a rainy season (December-May: average precipitation 1550 mm; 258.8 ± 36.8 mm/month) and a "dry" season (June-November: average precipitation 550 mm; 91.8 ± 43.8 mm/month and each month with some rain events; cf. Ribeiro & Adis, 1984). The yellow latosol (= ferrasol in Jordan, 1984) of the secondary upland forest is supported by a 2-3 cm thick humus layer, interspersed with fine roots, and a thin surface covering of leaf-litter. One ground photo-eclector (emergence trap) and one arboreal photo-eclector for trunk ascending invertebrates (funnel trap) were installed in the forest (cf. Adis & Schubart, 1984) and remained there from December 1981 to December 1982. The distribution of schizomids in the soil was studied between September 1982 and August 1983 (Rodrigues, 1986). Twelve soil samples were taken once a month every two meters along a randomly selected transect. The split corer, composed of a steel cylinder with lateral hinges (diameter 21 cm, length 33 cm), was driven into the soil by a mallet. Each sample of 7 cm depth was then divided into two subsamples of 3.5 cm each for extraction of animals, following a modified Kempson method (Adis, 1987). The combined area of the 12 samples represented 0.42 m^2. Calculated average abundances per m^2 are given with sample standard deviation. The monthly collection data of schizomids from the two soil layers in relation to changing abiotic conditions (precipitation, temperature and humidity of the air near the forest floor; moisture content, temperature and pH of the soil) were statistically evaluated with a linear, parametric correlation test (Cavalli-Sforza, 1972) using the original field data (cf. Rodrigues, 1986). All Schizomida sampled were classified as juveniles, subadults and adults (males and females, respectively; cf. Reddell & Cokendolpher, 1995). Juveniles were tentatively assigned to three size classes, based on measurements of the cephalothorax length. They presumably represent the three development stages in nymphs, apart from the subadult stage (cf. Brach, 1976; Dumitresco, 1973; Rowland, 1972).

Voucher specimens have been deposited at the Systematic Entomology Collections of the Instituto Nacional de Pesquisas da Amazônia (INPA) in Manaus/ Brazil, at the Texas Memorial Museum, Austin/ Texas and at the Muséum d'histoire naturelle in Geneva/Switzerland.

RESULTS

Schizomida obtained from the secondary upland forest under study at Rio Tarumã Mirím were represented by *Surazomus mirim* and *S. rodriguesi* (cf. Cokendolpher & Reddell, 2000) with 99.7% and 0.3% of the total catch, respectively.

A total of 357 schizomids was collected. Out of these, 99% were identified to their developmental stages. Schizomids were mostly found in the soil and never caught on tree trunks. Only one specimen was captured in a pitfall trap inside the ground photo-eclector while active on the soil surface. Schizomids represented 0.3% of the total arthropods extracted from soil samples within 12 months (excluding Acari & Collembola; cf. Rodrigues, 1986). Their abundance in 0-7 cm soil depth was lower than that of the Palpigradi (722 versus 1141 ind./m^2), whereas abundance of the Thelyphonida (7 ind./m^2) was even lower (cf. Adis *et al.*, 1997a). This is also true for the dominant species in each group (Fig. 1; Adis *et al.*, 1999). An average abundance of 60.4 ± 32.2 schizomids/m^2 /month was recorded in 0-7 cm soil depth (*S. mirim*: 60.2 ± 32.5 ind./m^2/month; *S. rodriguesi*: 0.2 ± 0.7 ind./m^2/month; cf. Table 1).

Most specimens of *S. mirim* inhabited the organic soil layer (Fig. 2: 0-3.5 cm) and a few (26%) the mineral subsoil (3.5-7.0 cm depth). About 70% (41.9 ± 21.9 ind./m^2/month) of the total catch was represented by juveniles (Fig. 2), 9% by subadults (5.8 ± 3.4 ind./m^2/month) and 21% by adults (12.5 ± 10.1 ind./m^2/month). Sex ratio (adult males to females) was 1:2.0 (all adults could be sexed). No significant difference between subadult males and subadult females was found for the cephalothorax length (Chi-square test). Juveniles could not be sexed.

The monthly abundance of *S. mirim* juveniles obtained from the organic soil layer (0-3.5 cm depth) was negatively correlated with soil temperature (23.8-26.4 °C; average: 25.3 ± 0.7 °C), i.e. catch numbers increased with decreasing temperatures (total catch: $r=-0.58534$, $p<0.05$; $n=12$). The total catches of specimens obtained during the dry season were higher than those in the rainy season: 63% versus 37%. However, there was no distinct reproductive period because juveniles (in particular the first nymphal instar) as well as adults (both sexes) occurred throughout the year (Figs. 3, 4). These results indicate a plurivoltine mode of life.

DISCUSSION

The data on abundance and vertical distribution of schizomid species in the secondary forest investigated can be compared with those obtained during a similar study between 1981 and 1983 in a primary upland forest on yellow latosol (Adis *et al.*, 1999). This primary forest was located at Reserva Florestal A. Ducke (= Reserva Ducke; 02°55'S, 59°59'W), about 26 km from Manaus. The total abundance of the two different schizomid species collected there (Table 1) was about 1.6 times higher than the total number of schizomids obtained from the secondary forest. This was also

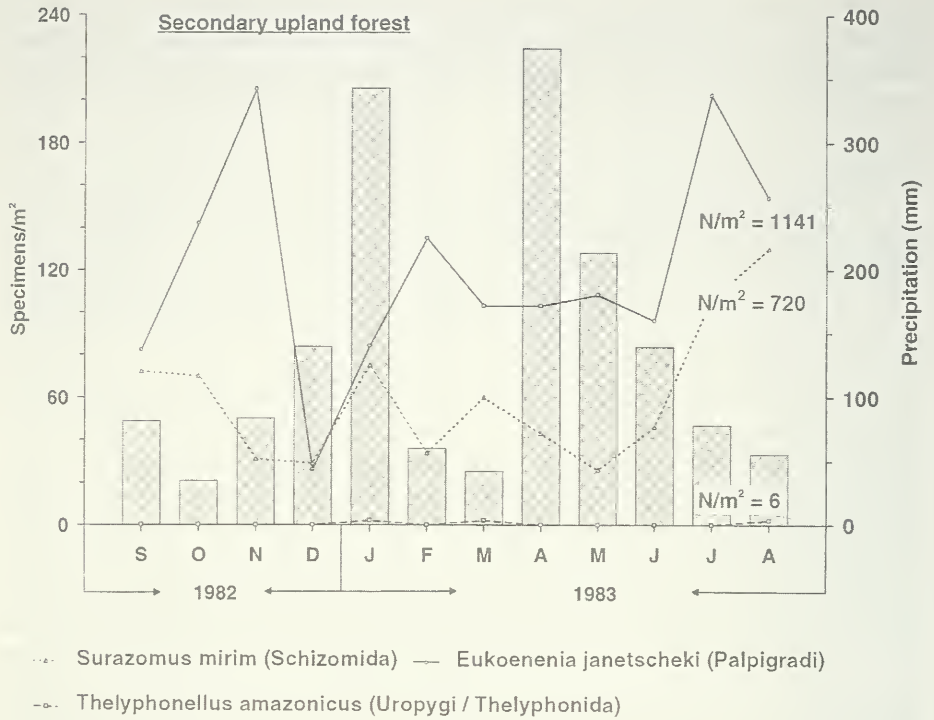

FIG. 1

Distribution of *S. mirim* Cokendolpher & Reddell (Schizomida), *E. janetscheki* Condé (Palpigradi) and *T. amazonicus* (Butler) (Thelyphonida) in the soil of a secondary upland forest near Manaus. Samples taken monthly at 0-7 cm depth between September 1982 and August 1983. (N = total number of specimens). Total precipitation per month given as bars between sampling dates (= in the middle of each month). The low rainfall observed in early 1983 was due to a strong El Niño-event (cf. Adis & Latif, 1996).

observed for the palpigrads (Table 1) and the geophilomorphs (Adis *et al.*, 1996), which both were four times more abundant in the secondary upland forest. In each forest type, one of the two schizomid species present was eudominant and more abundant in the organic soil layer (Table 1). The presence of juvenile schizomids seems to be influenced by soil temperatures: monthly abundances of *S. mirim* in the upper soil of the secondary forest were negatively correlated, whereas those of *S. brasiliensis* (Kraus) from the primary forest were positively correlated. One reason for this (see below) might be different microclimates, as annual average soil temperatures in the upper 3.5 cm were 1.5 °C higher in the secondary forest than in the primary forest (cf. Adis *et al.,* 1999).

Further comparable data on the abundance and vertical distribution of the soil fauna in four other upland forest types of Central Amazonia were obtained by Adis and collaborators (cf. Adis *et al.,* 1987a,b, 1989a,b; Ribeiro, 1994). During rainy and dry seasons arthropods were collected to a soil depth of 14 cm and extracted with the

TABLE I
Average abundance (N/m^2±SD) and dominance (%) of Schizomida species (all in the Hubbardiidae) and of *Eukoenenia janetscheki* (Palpigradi) in the soil of a primary and a secondary upland forest near Manaus, Brazil. Samples taken monthly at 0-3.5 and 3.5-7.0 cm soil depths between September 1982 and August 1983 (see text for details).

	N/m^2 per month			%
	0 - 3.5 cm	**3.5 - 7.0 cm**	**0 - 7.0 cm**	**0 - 7.0 cm**
Schizomida				
Primary upland forest				
Surazomus brasiliensis	24.4 ± 13.4	11.7 ± 7.6	36.1 ± 16.8	96.0
Adisomus duckei	-	1.4 ± 1.7	1.4 ± 1.7	4.0
Total	24.4 ± 13.4	13.1 ± 8.9	37.5 ± 16.8	100.0
Secondary upland forest				
Surazomus mirim	44.6 ± 25.9	15.6 ± 10.3	60.2 ± 32.5	99.7
Surazomus rodriguesi	0.2 ± 0.7	-	0.2 ± 0.7	0.3
Total	44.8 ± 25.7	15.6 ± 10.3	60.4 ± 32.2	100.0
Palpigradi				
Primary upland forest				
Eukoenenia janetscheki	6.5 ± 6.4	22.9 ± 15.7	29.4 ± 20.2	100.0
Secondary upland forest				
Eukoenenia janetscheki	33.7 ± 18.7	86.4 ± 37.8	120.1 ± 50.8	100.0

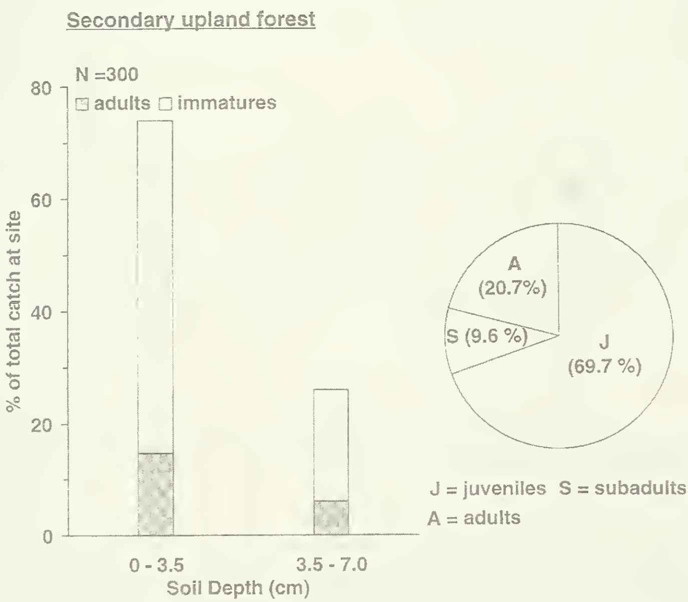

FIG. 2
Distribution of *Surazomus mirim* in the soil according to soil depth and percentage of developmental stages in a secondary upland forest near Manaus (total catch = 100%). Samples taken monthly at 0-3.5 and 3.5-7 cm depths between September 1982 and August 1983. (N = total number of specimens).

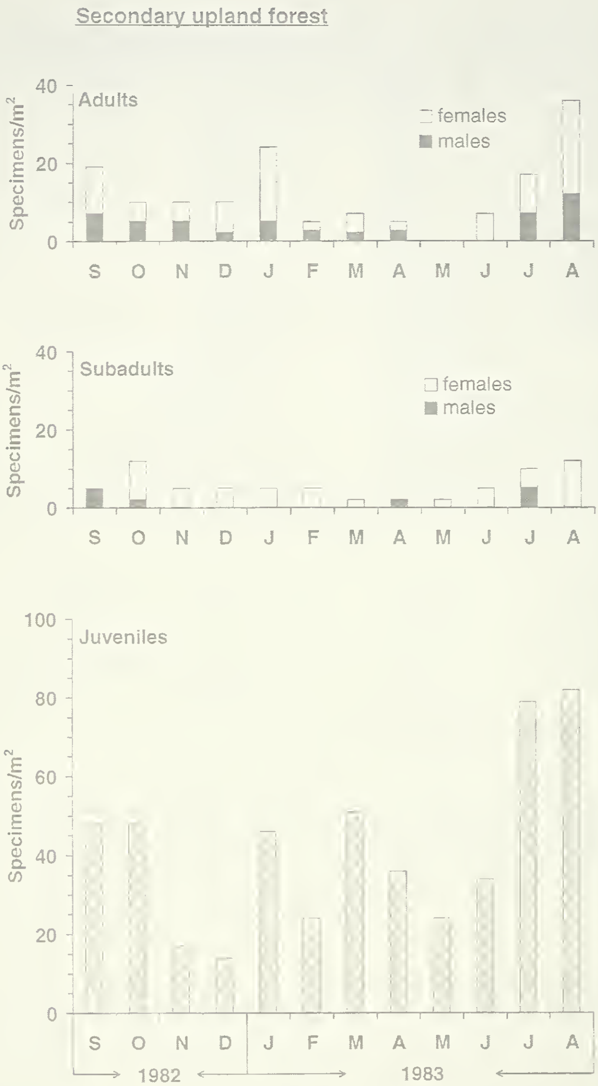

FIG. 3
Temporal occurrence of developmental stages of *Surazomus mirim* in the soil (N/m^2 in 0-7 cm depth) of a secondary upland forest near Manaus. Monthly samples taken between September 1982 and August 1983.

Kempson method as described above. Between 75% and 92% of all arthropods were found to inhabit the top 7 cm when Acari and Collembola were included in the total catch numbers and 69%-84% when they were omitted. Data on Schizomida are now available.

One study was conducted during October 1985 and April 1986 in a secondary upland forest on yellow latosol (Capoeira) at the INPA campus in Manaus (03°08'S.

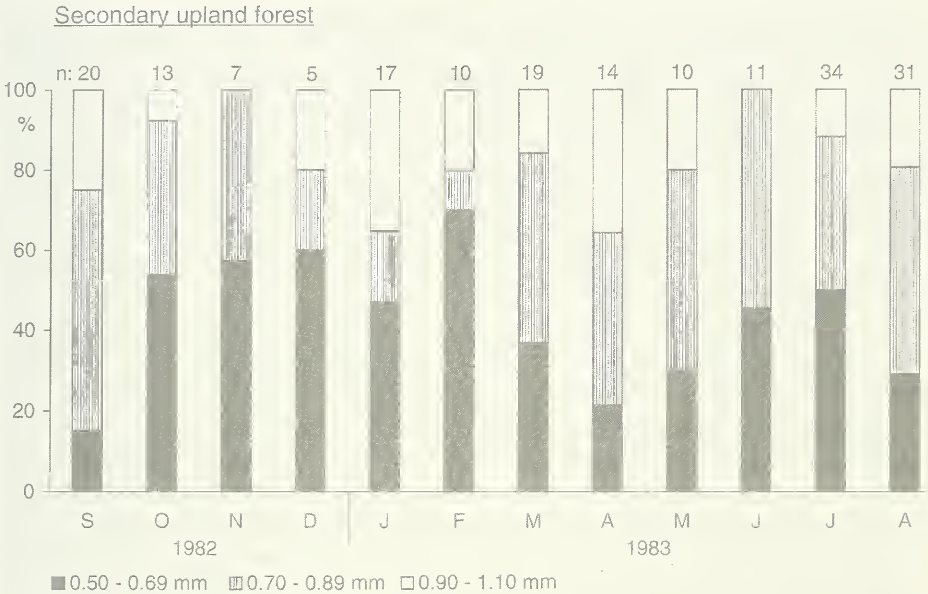

FIG. 4

Temporal occurrence of three tentatively assigned size classes (according to cephalothorax length) in juveniles of *Surazomus mirim*. Specimens, obtained from 0-7 cm soil depth, presumably represent the three developmental stages in nymphs, apart from the subadult stage. Monthly samples taken between September 1982 and August 1983 in a secondary upland forest near Manaus. (Number of specimens examined per month = 100%; 191 (91.4%) out of 209 juvenile specimens could be measured).

60°01'W), where the vegetation was previously cut but unburned (Adis *et al.*, 1987a,b). Schizomids represented 0.1% of the total number of arthropods when Acari and Collembola are included (dry season: 50.448 ind./m^2, rainy season: 63.850 ind./m^2) and 0.3-0.4% when they are omitted from the total catch numbers (dry season: 11.934 ind./m^2, rainy season: 17.886 ind./m^2). In the upper soil layer (0-7 cm depth), the abundance of schizomids during the dry season (48.1 ind./m^2) was similar to that of the rainy season (52.9 ind./m^2). No schizomids were caught in the mineral subsoil (7-14 cm) during both seasons. One species is presently known from this study site: *Surazomus manaus* (cf. Cokendolpher & Reddell, 2000).

Another study was made from August 1990 to February 1991 in a secondary upland forest on yellow latosol (Capoeira), about 50 km north of Manaus (03°34'S, 60°60'W), where the vegetation was previously cut and burned (Ribeiro, 1994). Schizomids represented <0.1% of the total number of arthropods when Acari and Collembola are included (dry season (Aug.-Oct.): 29.064 ind./m^2, rainy season (Dec.-Febr.): 19.793 ind./m^2) and 0.1% when they are omitted from the total catch numbers (dry season: 7.720 ind./m^2, rainy season: 7.176 ind./m^2). In the mineral subsoil (7-14 cm), the abundance of schizomids during the rainy season amounted to 9.6 ind./m^2 (50% of the total catch) but no specimens were here obtained during the dry season. The schizomid material from this study site was not available for identification.

A third study was made during March and August 1988 in a primary forest on whitesand soil (Campinarana), about 45 km north of Manaus (02°35'S, 60°01'W; Adis *et al.,* 1989a,b). Schizomids represented <0.1% of the total number of arthropods when Acari and Collembola are included (dry season: 57.703 ind./m^2, rainy season: 74.255 ind./m^2) and 0.2% when they are omitted from the total catch numbers (dry season: 14.119 ind./m^2, rainy season: 15.023 ind./m^2). The abundance of schizomids in the mineral subsoil (7-14 cm) during the dry season amounted to 14.5 ind./m^2 (50% of the total catch) but no specimens were here obtained during the rainy season. One species is presently known from this study site: *Surazomus brasiliensis* (cf. Cokendolpher & Reddell, 2000).

The fourth study was conducted during April and October 1987 in the primary upland forest on yellow latosol at Reserva Ducke (see above) (Adis *et al.,* unpubl.). Schizomids represented ≤ 0.1% of the total number of arthropods when Acari and Collembola are included (dry season: 38.727 ind./m^2, rainy season: 25.905 ind./m^2) and 0.1-0.2% when they are omitted from the total catch numbers (dry season: 11.742 ind./m^2, rainy season: 11.005 ind./m^2). The abundance of schizomids in the mineral subsoil (7-14 cm) during the dry and rainy seasons was similar (4.8 ind./m^2) and represented 20% and 50% of the total catch, respectively. Two species are presently known from this study site: *Adisomus duckei* and *Surazomus brasiliensis* (cf. Cokendolpher & Reddell, 2000).

All these data indicate that abundances of Schizomida (as well as of Palpigradi, Chilopoda and total Arthropoda) in formerly cut and unburned upland secondary forests on latosol of Central Amazonia are higher than in primary upland forests on latosol and whitesand soil. The reasons for this (e.g., different microclimates, more available food (particularly springtails, mites and termites) in secondary forests; cf. Adis, 1988; Morais, 1985; Rodrigues, 1986) remain to be clarified. However, in secondary upland forests which were formerly cut and burned, abundances of Schizomida, Chilopoda and total Arthropoda are generally lower within the first 15 years compared to primary forests (cf. Ribeiro, 1994).

Based on all studies hitherto realized on Central Amazonian schizomids in the Manaus region (cf. Cokendolpher & Reddell, 2000), *Adisomus duckei* and *Surazomus brasiliensis* might be potential bioindicators for primary upland forests whereas *S. mirim* and *S. rodriguesi* for secondary upland forests.

The low number of schizomids in samples from the ground photo-eclector in the secondary upland forest treated here indicates that representatives of this group were not active on the soil surface. This conclusion is supported by two other studies in the primary upland forest of the Reserva Ducke near Manaus: no schizomids were collected here in 20 baited pitfall traps and in one or several ground photo-eclectors during a sample period of 12 months (Adis *et al.,* 1999; Penny & Arias, 1982) or from tree crowns by fogging canopies with pyrethrum (cf. Adis *et al.,* 1998). Schizomida were not found in the soil of man-made pastures (0-14 cm depth) adjacent to upland forests in Central Amazonia. One reason for this might be the low humidity and high temperature of the soil around noon, particularly during the dry season (Adis & Franklin, unpubl.).

To which depth schizomids occur in the soil of Central Amazonian upland forests is unknown. Our studies in various forest types near Manaus (see above) revealed their presence to a soil depth of 14 cm.

Schizomids are easily mistaken for young spiders, particularly if their flagellum or front legs are broken. This might explain their "absence" in other studies on the Neotropical arthropod fauna in 0-30 cm soil depth (e.g. Harada & Bandeira, 1994a,b; Macambira, 1997; Serafino & Merino, 1978).

Parthenogenesis has been reported for several schizomid species (cf. Reddell & Cokendolpher, 1995). In. *S. mirim* both sexes were present. However, more than twice as many females as males were captured. This was also observed in *S. brasiliensis* from the primary upland forest at Reserva Ducke near Manaus (Adis *et al.*, 1999) and in the euedaphic palpigrad *Eukoenenia janetscheki* Condé (Adis *et al.*, 1997a). Predominance of females assures the continuation of a species. The number of females in three species of Symphyla from the secondary upland forest at Rio Tarumã Mirím and the primary upland forest at Reserva Ducke was 2-4 times higher than of males (Adis *et al.*, 1997b).

Different schizomid species were recorded in Central Amazonian upland forests when compared to those found in Central Amazonian inundation forests (cf. Cokendolpher & Reddell, 2000). The presence of non-winged terricolous arthropods in the latter biotope requires flood resistance, horizontal migration according to the high-water line or vertical migration onto the trunk or into the canopy in response to annual flooding of 5-7 months duration (Adis, 1997). Reproduction cycle and duration of life stages have to be synchronized with the periodic fluctuations in water-level (cf. Adis, 1997, 1988; Adis *et al.*, 1997b). So far our field data indicate that *S. brasiliensis* (primary upland forest) and *S. mirim* (secondary upland forest) do not meet two of these premises: the species were not collected on or above the soil surface and had no distinct reproductive period.

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